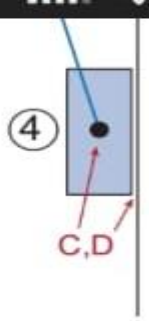
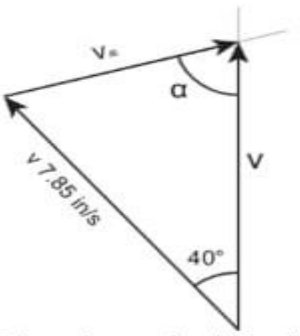
From the velocity polygon

$$\boxed{v_c = 9.4 \times \frac{7.85}{10} = 7.379 \text{ in/s}}$$

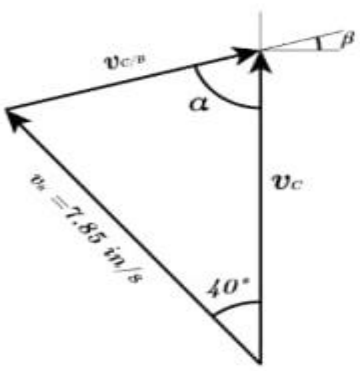


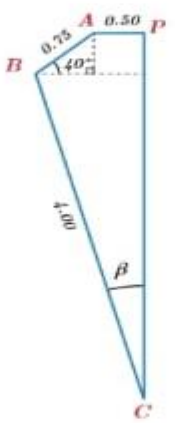
Analytical method:

For analytical method the following velocity diagram is used. The angle α must be known in order to solve the triangle.



The angle α can be obtained from the orientation of link 3. Considering the geometry of links in the kinematic diagram:





The angle β can be obtained as

$$\beta = \sin^{-1}\left(\frac{0.75\cos(40°) + 0.5}{4}\right) = 15.58°$$

Now the angle α can be obtained as

$$\alpha + 90° + \beta = 180°$$

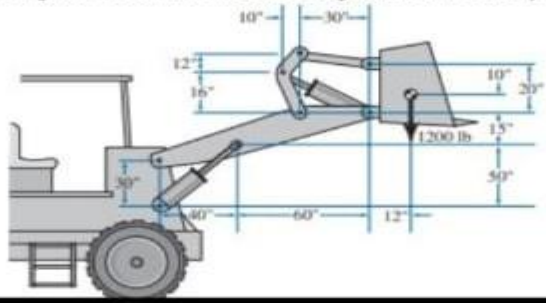
$$\Rightarrow \alpha = 90° - \beta = 90° - 15.58° = 74.42°$$

By using sine law, the velocity v_C can be obtained as

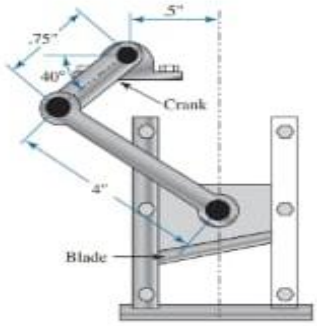
$$\frac{v_C}{\sin(180 - 40 - 74.42)} = \frac{7.85}{\sin(74.42)}$$

$$\boxed{v_C = 7.42 \text{ in/s}}$$

Q4. A front loader is shown in figure. Determine the force required from both hydraulic cylinders to maintain the shovel position.



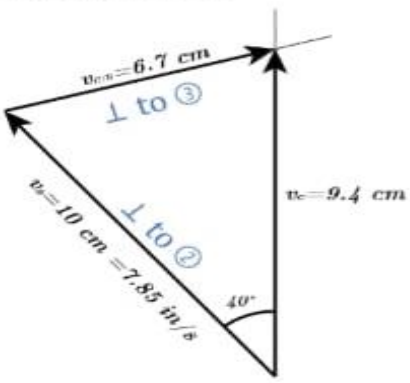
Q3. For the shearing mechanism in the configuration shown in Figure use the relative velocity method to graphically and analytically determine the linear velocity of the blade as the crank rotates clockwise at 100 rpm.

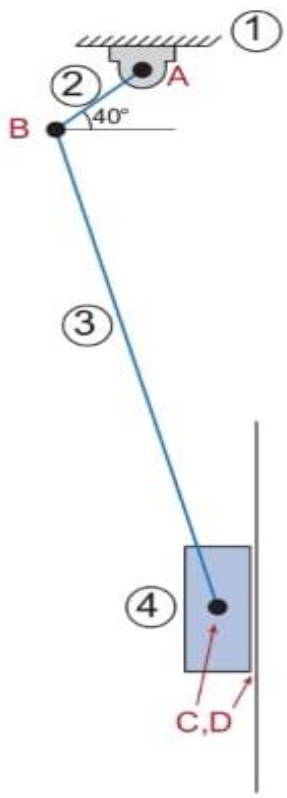


Solution

$$v_B = 0.75 \times \frac{100 \times 2\pi}{60} = 7.85 \text{ in/s}$$

Graphical method:



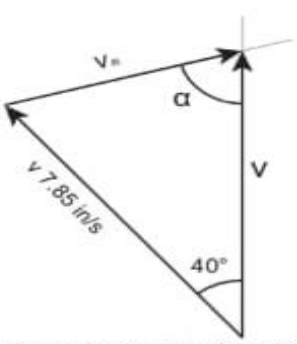


From the velocity polygon

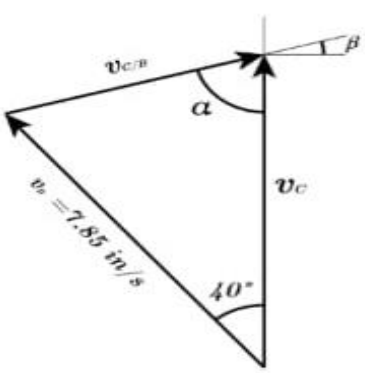
$$\boxed{v_c = 9.4 \times \frac{7.85}{10} = 7.379 \text{ in/s}}$$

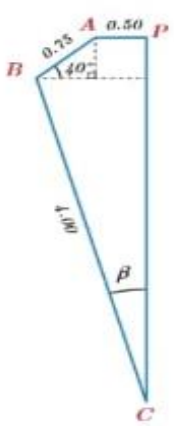
Analytical method:

For analytical method the following velocity diagram is used. The angle α must be known in order to solve the triangle.



The angle α can be obtained from the orientation of link 3. Considering the geometry of links in the kinematic diagram:

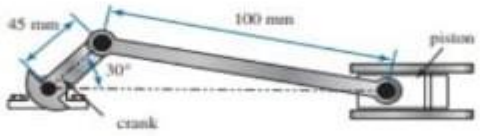




The angle β can be obtained as

$$\beta = \tan^{-1}\left(\frac{0.75\cos(40°) + 0.5}{\quad}\right)$$

Q2. Graphically position the links for the compressor linkage in the configuration shown in Figure. Then reposition the links as the 45-mm crank is rotated 90° counterclockwise. Determine the resulting displacement of the piston. Also analytically determine the linear displacement of piston.

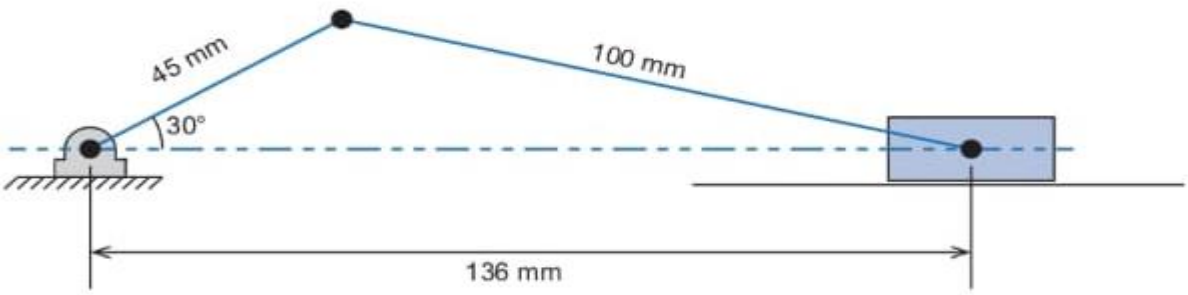


Solution

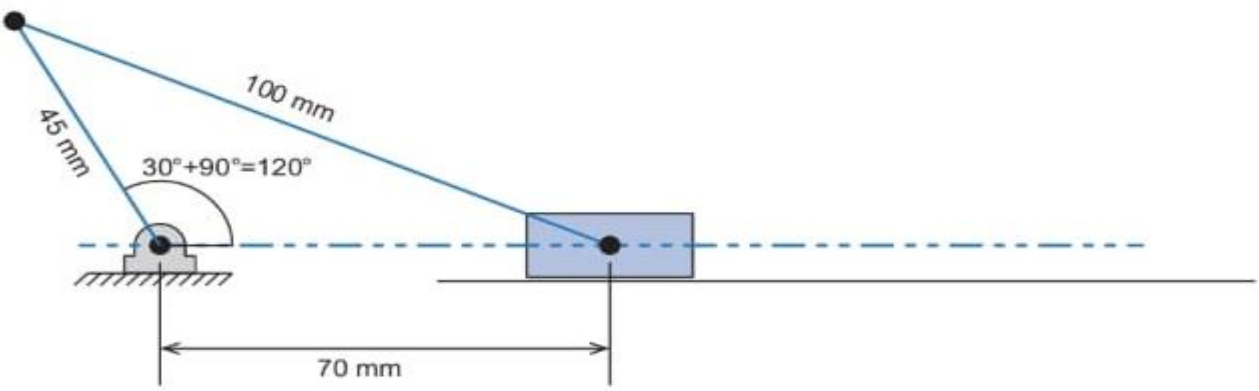
Graphical method:

Kinematic Diagram for the above mechanism is drawn.

- Initial position:



- Final position



Displacement is $70 - 136 = \boxed{-66 \text{ mm}}$ *Ans.*

Analytical method:

The initial position of the piston x for $\theta = 30°$ can be obtained using cosine law

$$100^2 = 45^2 + x^2 - 2(45)(x)\cos(30°)$$

$$\Rightarrow x = 136.40 \text{ mm}$$

The final position of piston x' for $\theta = 120°$ can also be obtained using cosine law

$$100^2 = 45^2 + x'^2 - 2(45)(x')\cos(30°)$$

$$\Rightarrow x' = 69.59 \text{ mm}$$

The displacement of piston is

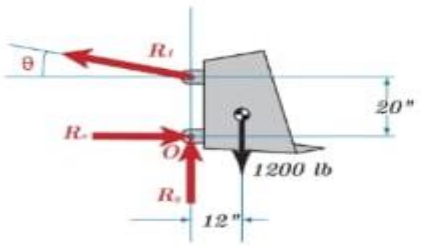
$$\Delta x = x' - x = 69.59 - 136.40$$

$$\boxed{\Delta x = -66.81 \text{ mm}} \quad \textit{Ans.}$$

For Cylinder-2 (Upper):

Consider the FBD of shovel, angle θ made by the reaction force R_1 can be determined as:

$$\theta = \tan^{-1}\left(\frac{8}{30}\right) = 14.93°$$

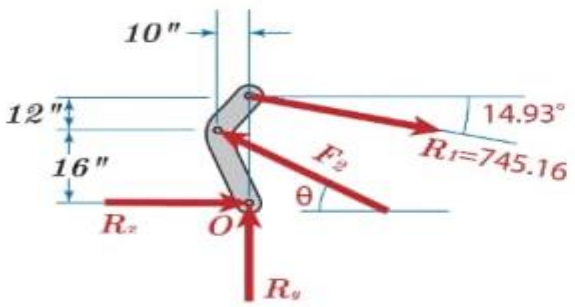


The moment about point O is to be zero and so:

$$(20) \times R_1 \cos(14.93°) - 12 \times 1200 = 0$$

$$\Rightarrow \boxed{R_1 = 745.16 \text{ lb}}$$

Now consider the FBD of the complex link and the upper cylinder



The angle θ at which the cylinder and thus the force F_2 is inclined is given by

$$\theta = \tan^{-1}\left(\frac{16}{40}\right) = 21.80°$$

The moment about point O is to be zero and so:

$$-(28) \times 745.16 \cos(14.93°) + 16 \times F_2 \cos(21.80°) - 10 \times F_2 \sin(21.80°) = 0$$

$$\Rightarrow \boxed{F_2 = 1809.36 \text{ lb}} \quad \textit{Ans.}$$

Q5. A horizontal engine running at 250 RPM has a bore of 200mm and stroke of 400mm. The piston rod is 30mm in diameter and the connecting rod length is 960mm. The mass of the piston is 10kg and the frictional resistance is equivalent to the force of 400N. Determine the following when the crank is 120 degrees from the top dead centre, the mean pressure being 0.45MPa on the top side of piston and 0.1MPa on the crank side

1- Thrust on the connecting rod
2- Thrust on the cylinder walls
3- Loading on the bearing 4- Turning moment of crank

Q6. The connecting Rod of a horizontal reciprocating engine is 500mm and the length of the stroke is 300mm. The mass of the piston is 110kg and the connecting rod is 130kg. The radius of gyration of the connecting rod about an axis through the centre of gravity is 130mm and the distance of centre of gravity of the connecting rod from big end bearing is 160mm. The Engine runs at 800RPM. Determine analytically the torque exerted on the crankshaft when the crank has turned 30 deg from the top dead centre.

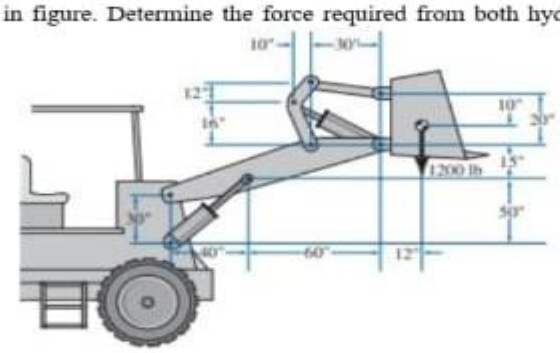
$\Rightarrow \alpha = 90° - \beta = 90° - 15.58° = 74.42°$

By using sine law, the velocity v_C can be obtained as

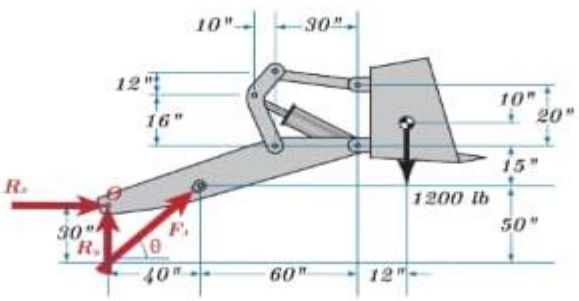
$$\frac{v_C}{\sin(180 - 40 - 74.42)} = \frac{7.85}{\sin(74.42)}$$

$$\boxed{v_C = 7.42 \text{ in/s}}$$

Q4. A front loader is shown in figure. Determine the force required from both hydraulic cylinders to maintain the shovel position.



Consider the following FBD of mechanism with bottom cylinder removed. (Note that the bottom cylinder is a two-force member thus the force is in the direction θ of the member)



Solution

For Cylinder-1 (Bottom):

The angle θ made by the force F_1 from horizontal is:

$$\theta = \tan^{-1}\left(\frac{50}{40}\right) = 51.34°$$

The moment about point O is to be zero and so:

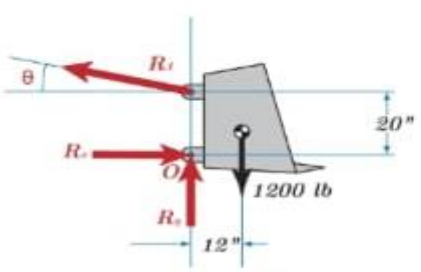
$$(40) \times F_1 \sin(51.34°) - (20) \times F_1 \cos(51.34°) - 112 \times 1200 = 0$$

$$\Rightarrow \boxed{F_1 = 7171.55 \text{ lb}} \quad \textit{Ans.}$$

For Cylinder-2 (Upper):

Consider the FBD of shovel, angle θ made by the reaction force R_1 can be determined as:

$$\theta = \tan^{-1}\left(\frac{8}{30}\right) = 14.93°$$

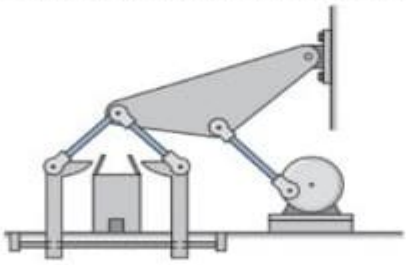


NED University of Engineering and Technology

Kinematics and Rigid Body (MC-514)

Submission Deadline: 14th July 2023 Marks: 20

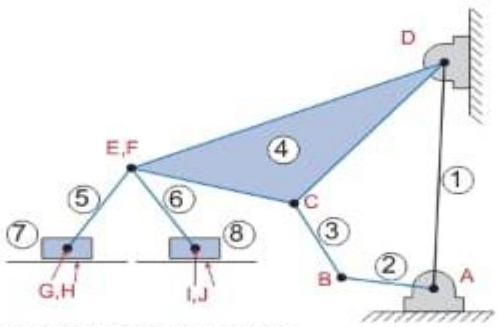
Q1. A sketch of a device to close the top flaps of boxes is shown in Figure. Draw a kinematic diagram of the mechanism, specify the number of links and the number of joints and calculate the mobility for the mechanism.



Solution

Kinematic Diagram:

Kinematic Diagram for the above mechanism is drawn.



The mechanism consists of 8 links and 8 pins + 2 sliders and thus,

$$n = 8, \quad j_p = (8 + 2), \quad j_h = 0$$

Mobility

Using Gruebler's equation

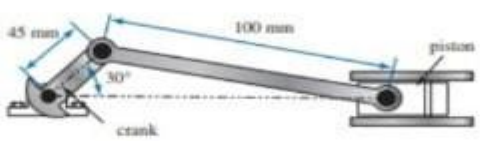
$$m = 3(n - 1) - 2j_p - j_h$$

$$m = 3(8 - 1) - 2(10)$$

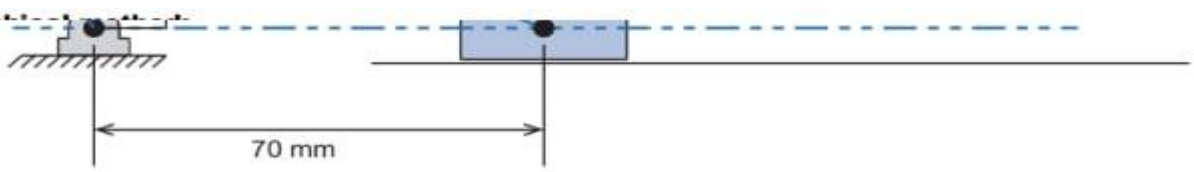
$$m = 21 - 20$$

$$\boxed{m = 1}$$

Q2. Graphically position the links for the compressor linkage in the configuration shown in Figure. Then reposition the links as the 45-mm crank is rotated 90° counterclockwise. Determine the resulting displacement of the piston. Also analytically determine the linear displacement of piston.



Solution



Displacement is $70 - 136 = \boxed{-66 \text{ mm}}$ *Ans.*